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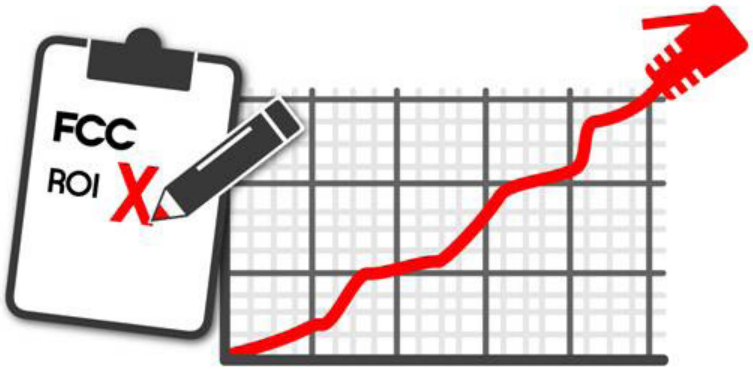
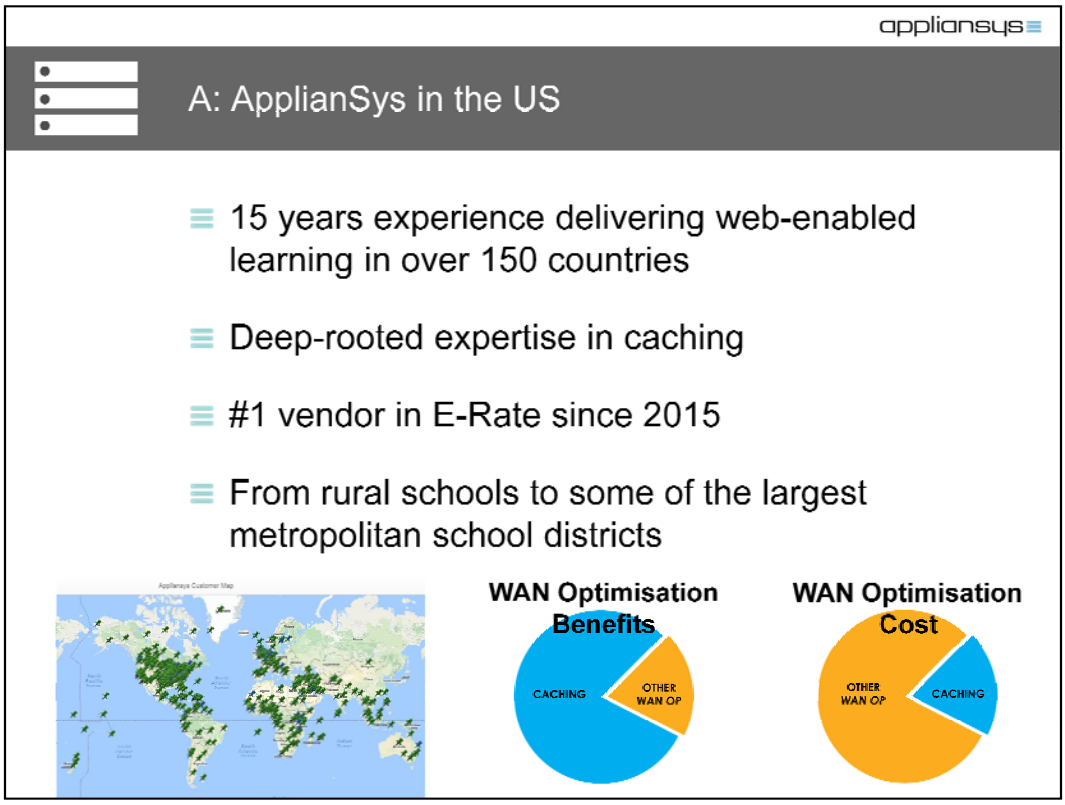
Caching to improve E-Rate ROI

ApplianSys Presentation to the FCC - August 7 2017



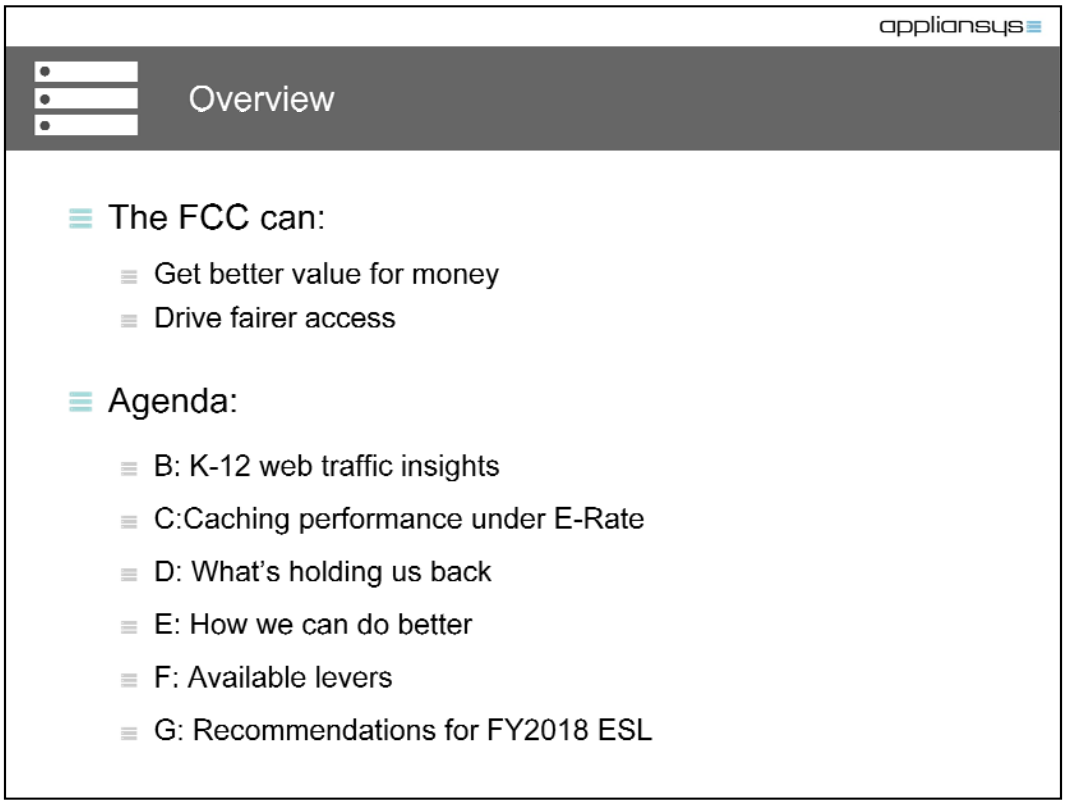


ApplianSys has been working with schools to optimise their Internet connections for more than 15 years, now in 150 countries.

Caching is both the most effective AND the most cost-effective WAN optimization technology. In K-12 we estimate that caching delivers 80% of the value of all other WAN optimization technologies combined, at around 20% of the price. And that's because caching works particularly well in the K-12 school environment.

Our caching appliance, **CACHE**BOX, has been the most widely selected caching solution by far in the E-Rate program since 2015. It is the only schools-focused solution in the sector that handles 'whole school' traffic patterns - including HTTPS, software updates, video and LMS password protected materials.

Traffic data from K-12 schools in over 40 states, from small rural schools to some of the largest metropolitan school districts, has demonstrated how bandwidth and caching should be combined to deliver best value for money.



We advocate that the FCC can:

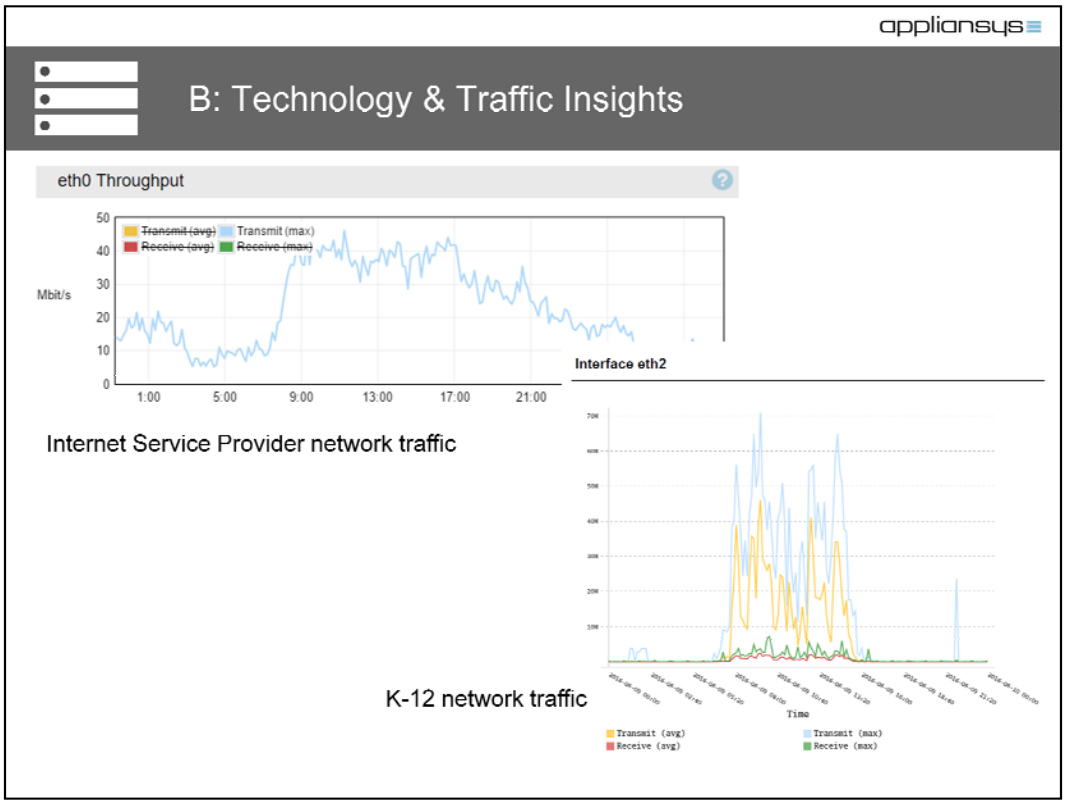
- Leverage more effective bandwidth per dollar
- Address cost-inefficiencies
- Ensure equitable access to digital learning under E-Rate program

Share our observations, analysis and real-world evidence on:

- Why modern K-12 web traffic mandates a re-think of the focus on bandwidth
- Success of caching in schools beyond initial expectations
- Factors behind broadband overspend, inequality of digital access and slow uptake of caching
- Bridging the Digital Divide with better targeting of E-Rate funds
- Specific ways to use the levers of funding, education and targets to effect change
- Recommended amendments to proposed FY2018 ESL

B: Technology & Traffic Insights

- Peaks 6-7x sustained
- Peaks are Highly Cachable
- Bandwidth to cater for peaks gives poor ROI
- Targets not cache-savvy
- Excessive bandwidth has hidden costs
- Slow Internet delivery speeds -
  even on multi-gigabit links
- Software disrupts WAN & LAN



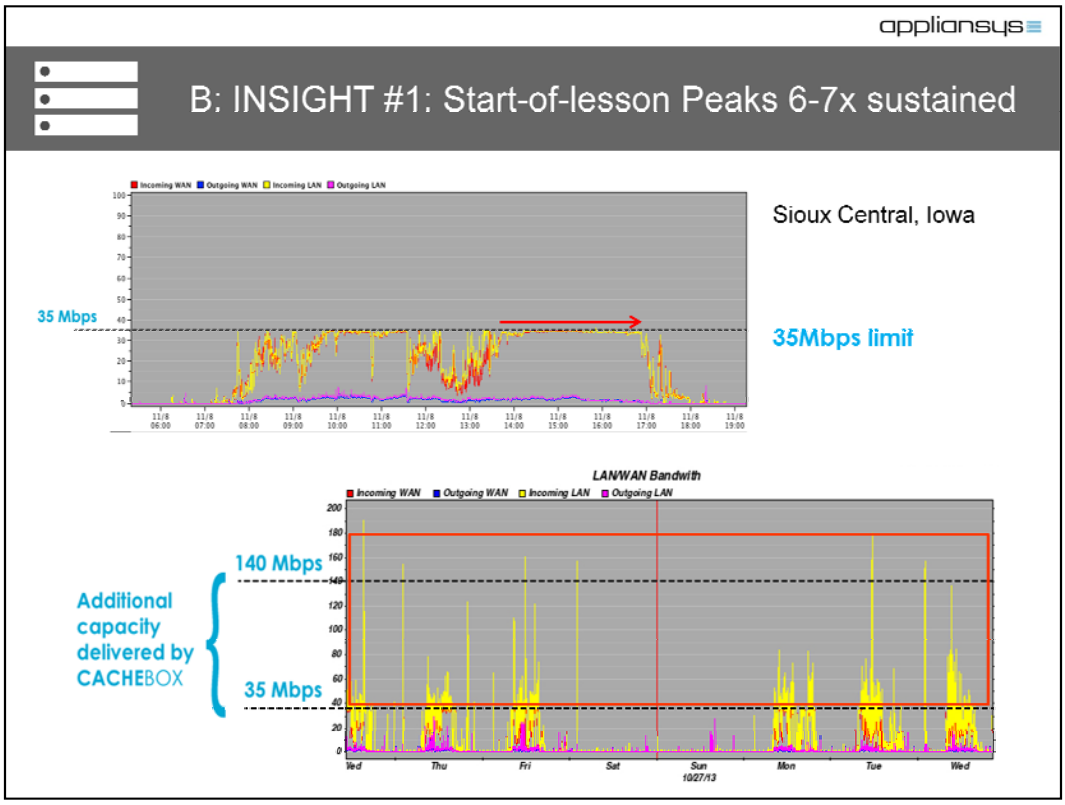
The K-12 web-traffic profile and its consequences:

• Traffic ebb and flow in K-12 is unique – a very spikey profile with large peaks at the start of each lesson dropping back to a fraction of that demand for the rest of the lesson.

• Peaks typically occur when, for example, 30 students are all directed to the same content at the same time – that's 29 copies of the request made by the first student.

• Those peaks define the amount of bandwidth capacity needed to prevent congestion - which results in poor ROI from annual bandwidth upgrades.

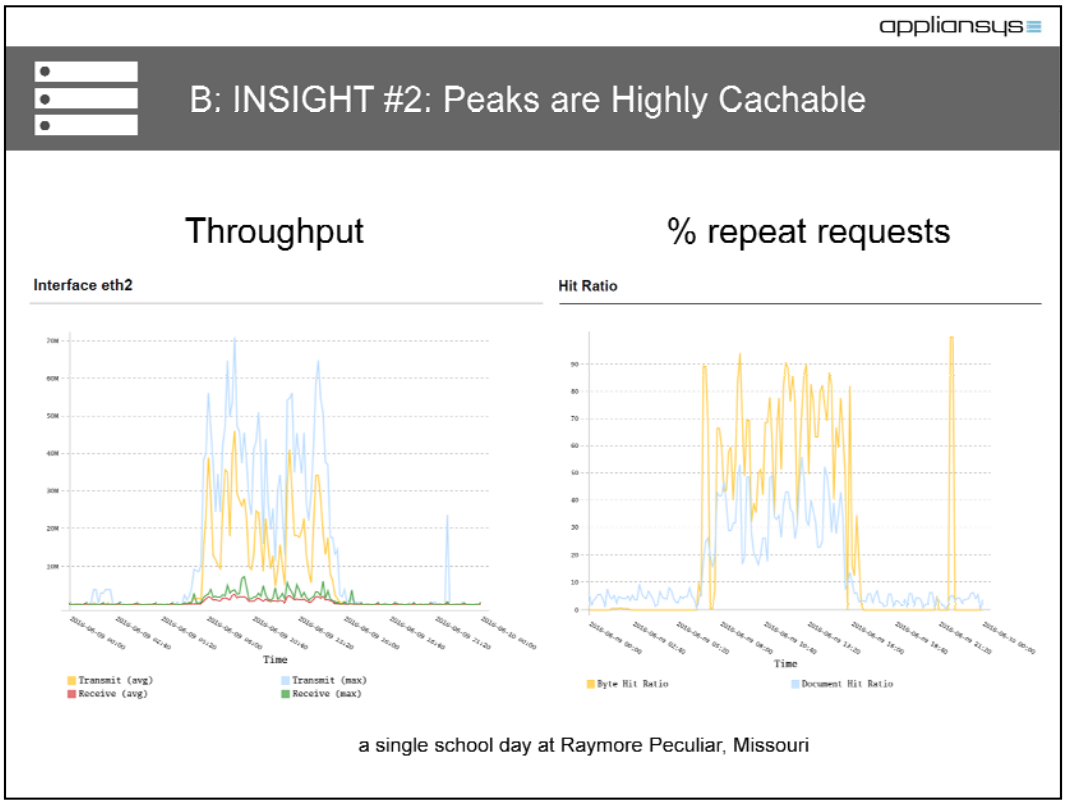
• Those unique peaks present an opportunity for caching to have a remarkable impact in K-12.



If a school doesn't have enough bandwidth to meet the peak demand then congestion occurs. The Internet connection flat-lines as it did here at Sioux Central in rural Iowa (top graph). Teachers were simply unable to use the 35Mbps Internet for independent Internet-enabled learning with 600 Students

The district installed a cache which can be seen (bottom graph) responding to those peaks in requests, delivering up to 140Mbps – even towards 200Mbps – on that existing 35Mbps connection.

(Graphs provided courtesy of AEA - Prairie Lakes)



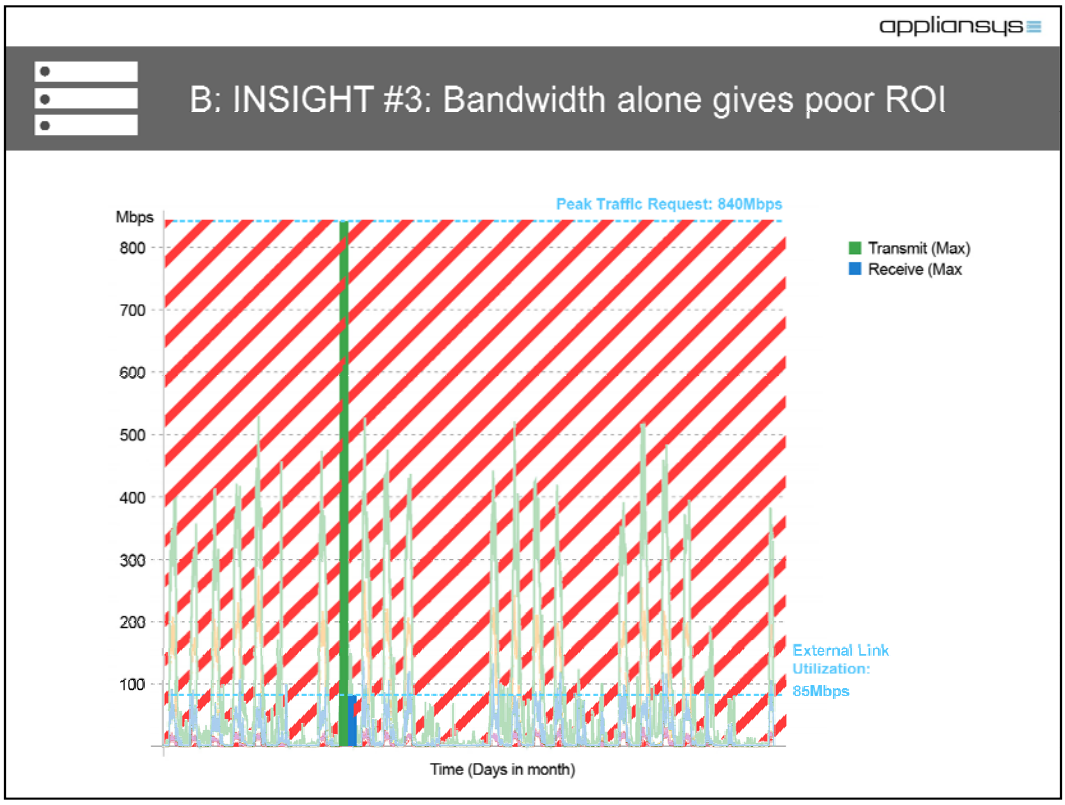
K-12 peaks are delivered very effectively by caching because they consist largely of repeat requests.

Peaks result from whole classes of students all directed to the same content at the same time.

Demand peaks (graph left) correlate closely with cacheability (graph right).

With the right caching solution, 90% or more of the bandwidth used from that set of repeat requests can be saved:

• At Raymore Peculiar school (above left), the incoming Internet (dark green line at bottom) is maxing at about 8Mbps of unique traffic while demand, including duplicate traffic delivered by the cache, peaks at up to 70Mbps (light blue at the top)



So as a result those peaks in Internet demand are cut right down to size by caching.

St Paul Public Schools in Minnesota have caches in their largest high schools.

They each have peaks in demand of around 800, 900, 950Mbps.

Example above is Central High – where green is the demand from the students and staff peaking at over 800Mbps – yet blue is what those users actually draw from the Internet – well below 100Mbps.

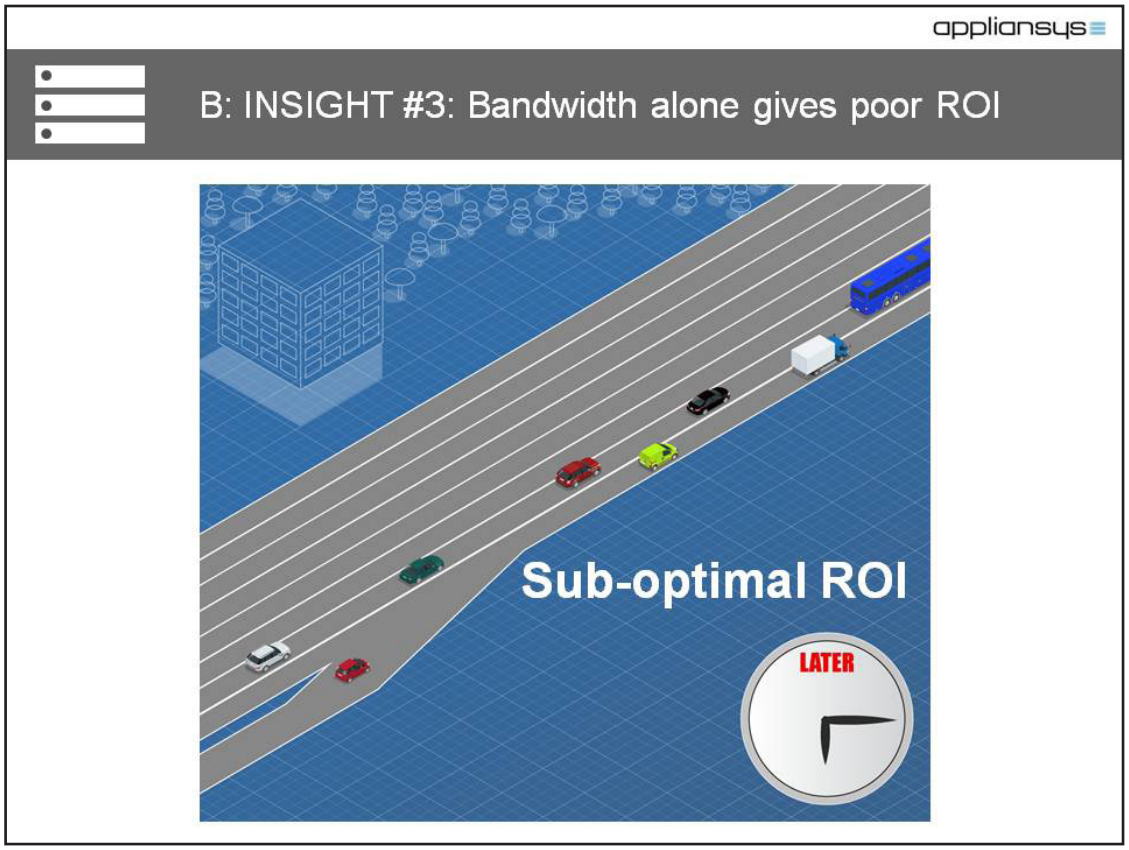
So a 100Mbps connection with a cache can deal with such demand spikes.

But without a cache, to meet that demand the school would need a 1Gbps connection- JUST for those start of lesson peaks.

But then that 1Gbps would be unused MOST of the time.

This red shaded area is the amount of unused capacity each High school would have if it purchased bandwidth to cover those peaks - without caching.

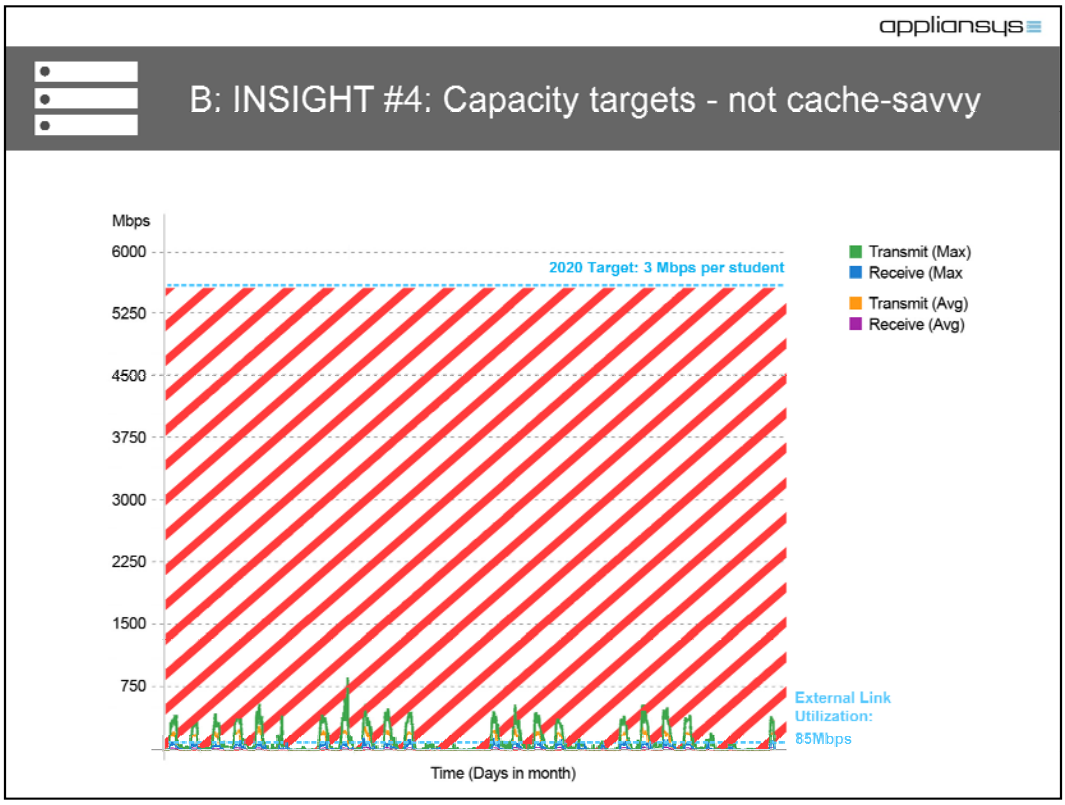
Without caching, this High School and the other 8 in the district would each draw around a Gig from the main Internet connection – so there's 9 Gig of their 10Gig link gone already - and then there are 74 other schools in the district. There wouldn't be enough capacity. Yet with caching in place they only utilise 2.5Gbps of that external link.



Using the analogy of highway infrastructure and periodic traffic congestion as an example, maintaining enough capacity to deal with enormous peaks that are momentary would mean masses of unused capacity – which somebody somewhere is paying for.

Consequently, it's not a great use of public money.

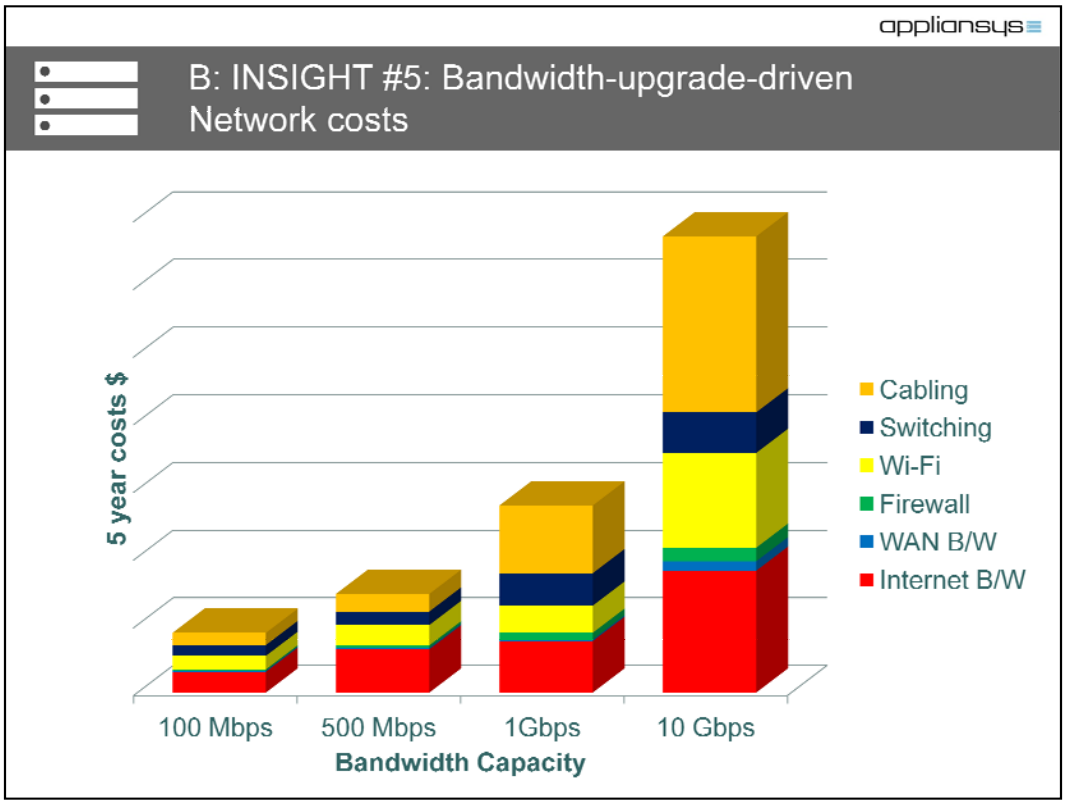
Bandwidth connectivity to cater for peak capacity demand does not deliver satisfactory ROI in K-12 because of the nature of this peak demand.



The 1Mbps/student connectivity target for 2018 for this school is drastic against this backdrop of potential waste (red shading).

For a school like this which utilizes caching to deal with peak web-traffic demand, it's hard to imagine what might happen between now and 2020 to require a 3Mbps/student target.

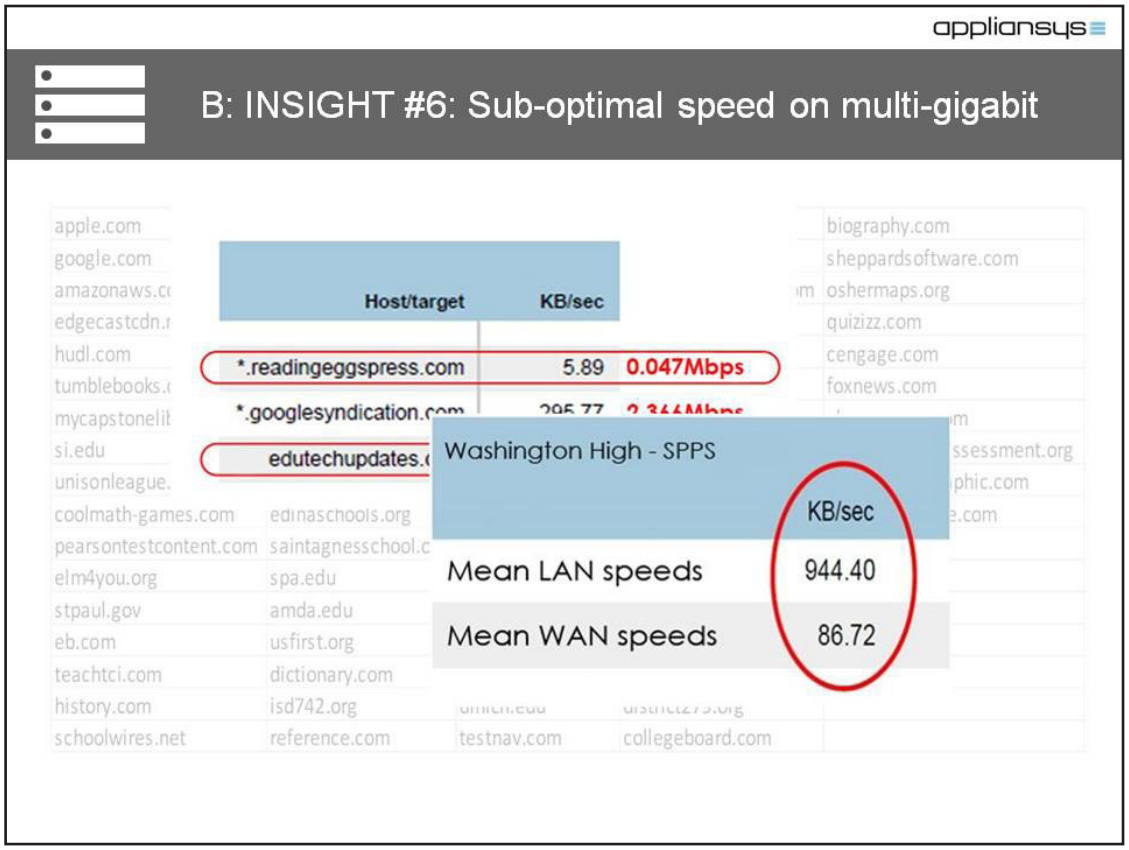
When considering this 2020 target for the same school (shown above, wastage in red shading) the potential for unnecessary costs is immense.



The unnecessary costs of extra bandwidth is compounded further when you take into account the extra infrastructure costs.

Moving over a throughput threshold means firewall or filter systems need to be upgraded – the costs involved in a multi-school district can be immense, particularly at key thresholds such as 100 and 500Meg, and 1 and 10 Gig.

With caching, that next bandwidth capacity upgrade of every school in the nation could be delayed by a year or more, and the savings would be substantial.

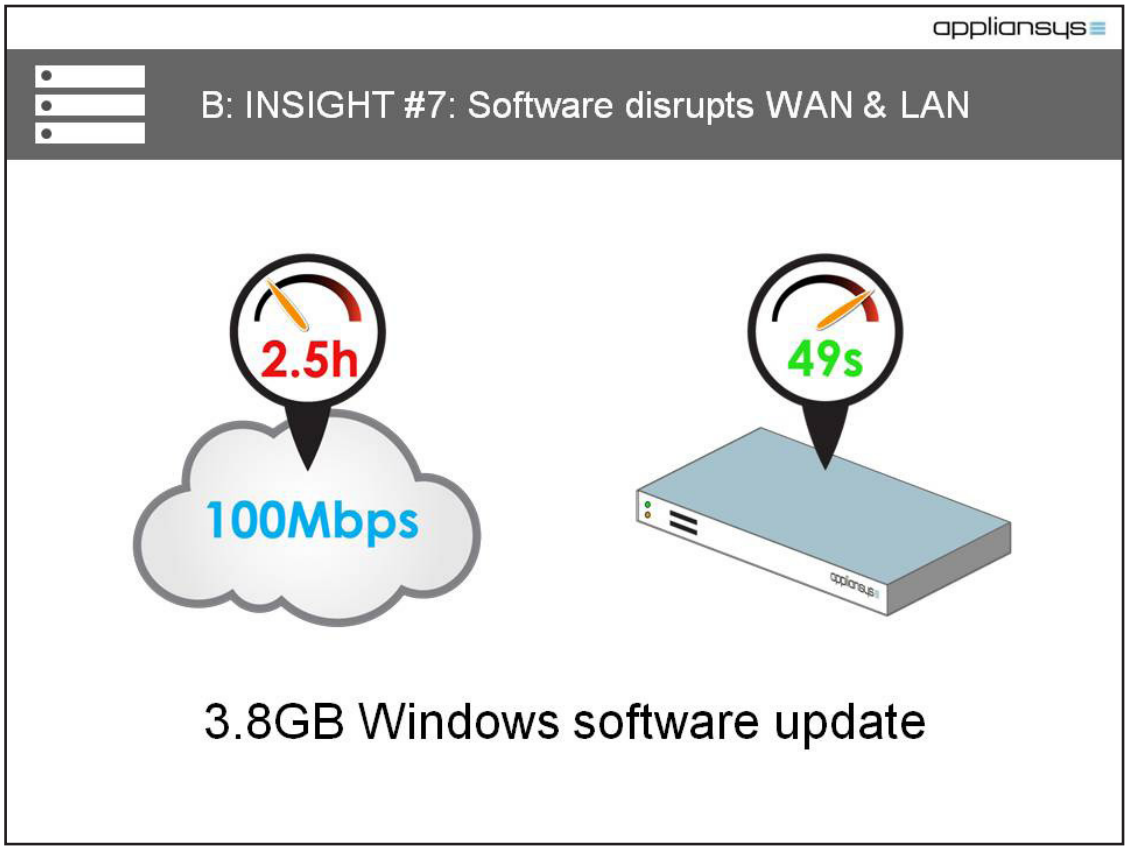


Does the annual bandwidth upgrade guarantee for schools the snappy and responsive browser performance that modern teaching and learning demands? The simple answer is no.

In a single high school (Washington High in Minnesota):
• hundreds of Educational sites are accessed in a single day
• they arrive at the network edge at a huge variety of speeds – some extremely slow even when the 10Gig link is completely underutilized

Caching serves that content at LAN speeds, typically 10-20x faster, often far more, even on a 10Gig Internet connection

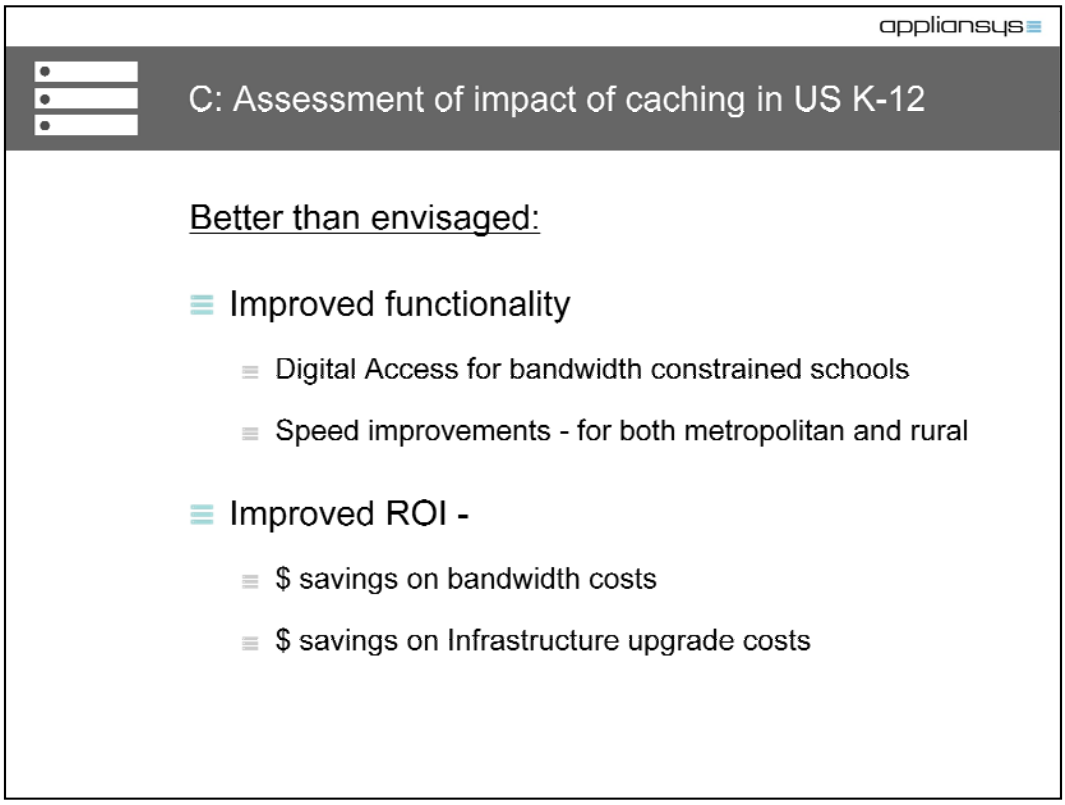
Let's just put this speed into context - just 3 secs average page load means you have 5% less time to answer questions in an online arithmetic test than students in a district with lightning fast browser speeds. And accumulated browser wait at those relatively modest levels can account for more than a week of lost teaching & learning time in a high school career.



Networks rely on the Internet for the delivery of software – which can account for the majority of network traffic on any given day.

School district networks are plagued with ever-growing data-flows that clog up both the WAN and Wi-Fi networks for hours at a time because those updates download at just a few Mbps, even on large and uncongested external connections.

In networks with appropriate caching, massive objects like multi-gigabyte Windows update files clear the LAN fast, and instead of thousands, only one copy needs to be fetched over the WAN.



Armed with an understanding of those insights from Section B, we can identify underlying drivers of E-Rate funded caching performance across K-12, and 4 groups of performance outcomes emerge that suggest that caching is achieving far more than anticipated.

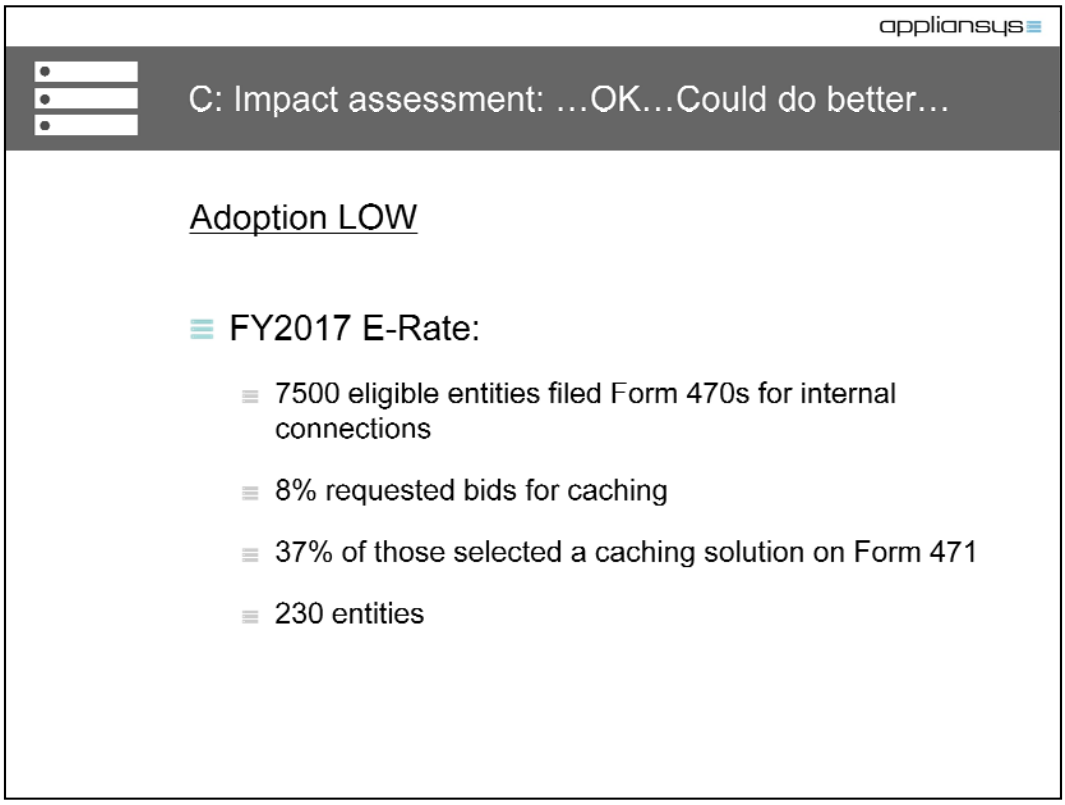
Rural - In terms of improved broadband functionality, there are many examples right across the country of rural schools where broadband simply didn't support Internet-enabled independent learning and was then transformed by the deployment of a cache – at a stroke changing the life-chances of pupils in rural communities. EducationSuperHighway estimates that 24% of students in remote schools across the US are on the wrong side of the Digital Divide.

Metropolitan - What may be more surprising is that even large metropolitan districts like St Paul Public Schools and Anaheim Union on a 10Gig link are extracting enormous benefit from caching, with classroom content between 10 and 50x faster

Cost savings - Beyond functionality there is a reduction in costs. Woodland in Chicago saved more than $100k over 5 years by deploying a cache on their 250Meg link. Durant in Idaho deployed a cache instead of a bandwidth upgrade which would have cost $33k/month, 100x more than the cache! We estimate that every district in Kentucky could slash the cost of their local connections, and then the Kentucky Department of Education could save towards $1m/year on top.

Infrastructure savings - And the last group of reported benefits encompasses reductions in infrastructure spend as a result of deploying a cache, affecting very large districts like San Bernardino in California and countless smaller districts like McGregor ISD in Minnesota – all avoiding firewall and filter upgrades.

See Appendix for a detailed dossier of the results of these and other schools.



Yet surprisingly few schools are utilizing E-Rate funding to implement caching.

We estimate that

• only about 8% of over 7,500 eligible entities filing Form 470s requested bids for caching

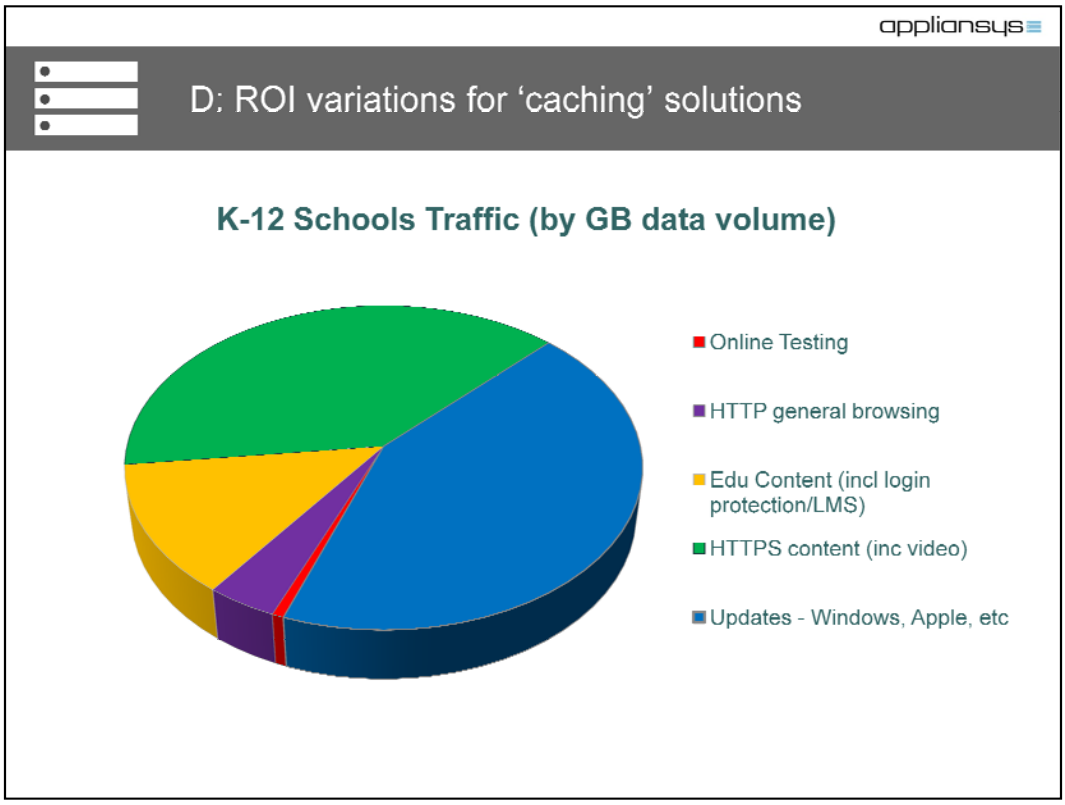
• only 37% of those actually selected a caching solution

• some of those were ‘single domain’ or ‘partial’ caches serving just a single website, online testing content, or Windows or Apple Cache, and therefore will not be delivering the whole-school benefits on the same scale as we have just been talking about.

D: Analysis: Waste & Low Adoption

- Bandwidth is prioritized
  - Sits in Category 1, Reinforced by Targets
  - Misconceptions about caching
  - ROI not worked through
  - Hidden costs not factored in
- Caching competes for funding with Wi-Fi
- SPEED is the goal. Contributors:
  - Capacity (bandwidth, caching)
  - Accelerating Slow Content (caching)
  - Internal Distribution (Wi-Fi, cabling)

Other goals: Affordability (caching), Safe Distribution (firewall, filters)



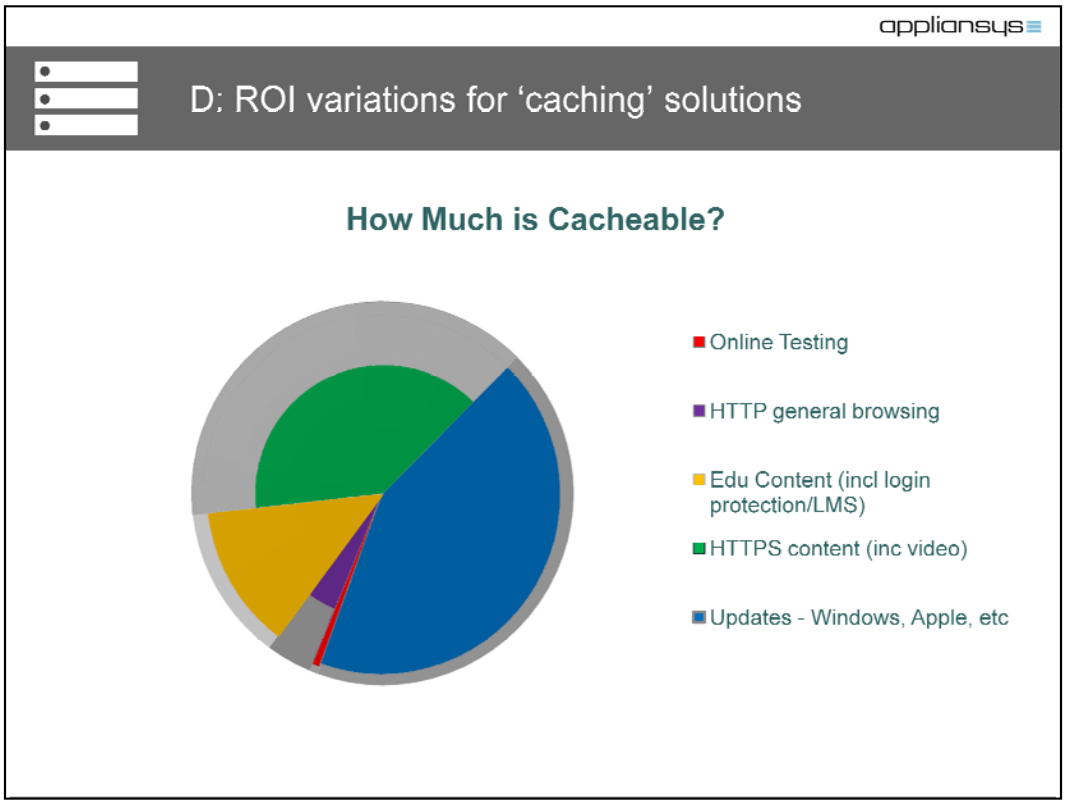
Out-of-date perceptions about caching continue to limit uptake by schools.

Even the technology departments of very large school districts with numbers of experienced IT professionals in the team base their expectations of caching capabilities on how things were around 10 years ago.

Most mistakenly believe that:

- HTPPS - a principal component of e-learning content - cannot be cached
- More complex modern traffic and dynamic content cannot be cached
- The move towards LMS single sign-on and other Login-protected materials renders caching unfeasible
- And they remember that functionality was so basic back then and assume that it's likely to be the case now that a cache might serve out-of-date content.

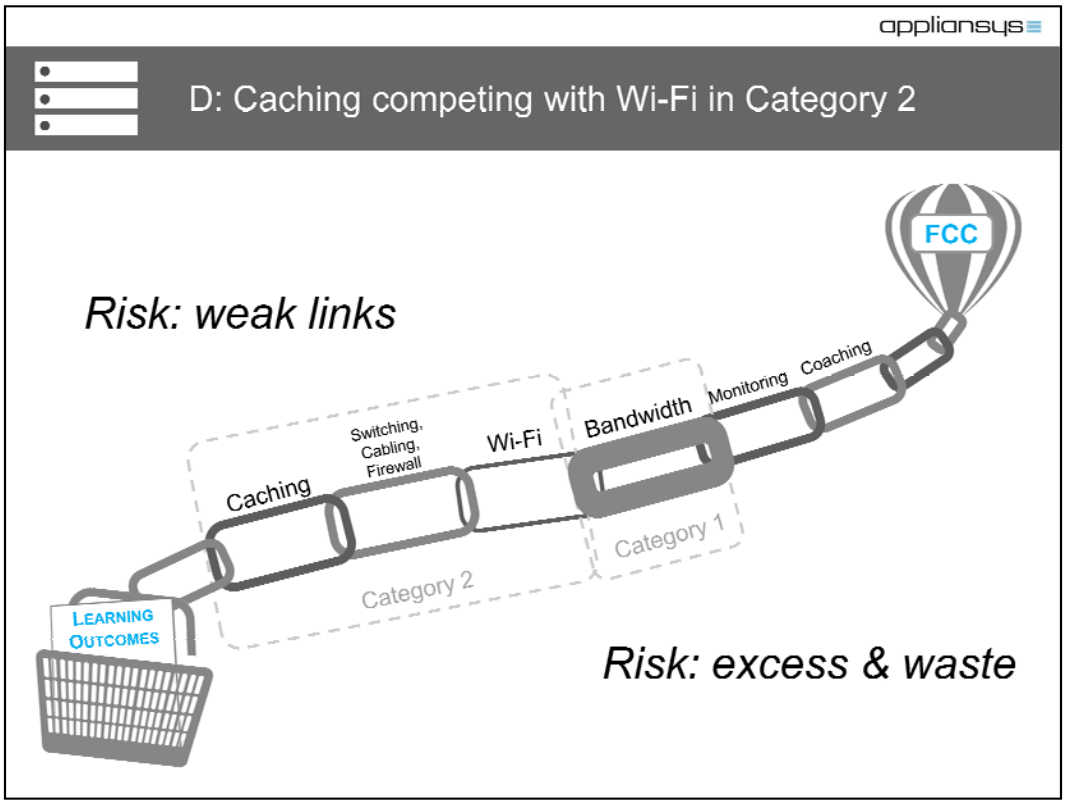
It is true that the composition of web traffic is very different from that of a decade ago, but school-focused caching has kept pace with those developments.



Many materials can be pre-fetched – loaded into memory before they are needed. It's not unusual for 95% or more of educational content, software updates and online testing to be delivered from cache.

That's great news for online testing – with a more flexible and responsive process and potential for massive reduction in expense compared with administering paper tests. It needs to be remembered though that online testing accounts for a very small proportion of school bandwidth, so while caching of testing materials is important and welcome in States where it is cacheable, it doesn't make a significant impact on the individual school's overall bandwidth or day-to-day teaching and learning demands.

Similarly a cache that acts only on a single application or website, or a single software type, will need careful ROI consideration to make a sensible comparison with bandwidth capacity, or indeed other caching solutions.

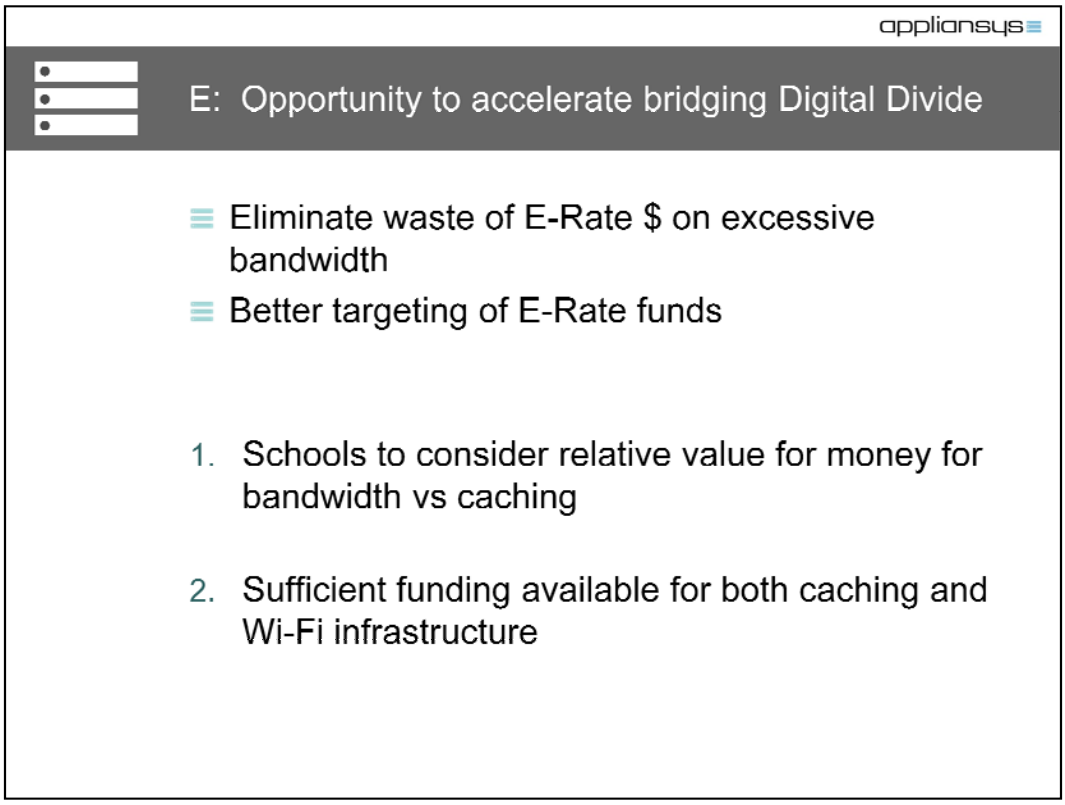


St John County School District in Florida is a large district with 32k students spread over 39 schools; they put caching first to the detriment of the Wi-Fi budget and consequently didn't see the full benefit of caching in schools with the old Wi-Fi setup until it was upgraded.

More commonly, schools often postpone caching until they have sorted out their Wi-Fi.

The e-learning network is an interdependent ecosystem; everything needs to be in balance. There's no value in pumping up one link in the chain disproportionately to the others because it's the weakest link that will define capability limits.

Caching is a substitute for bandwidth capacity – schools should have to choose between bandwidth and caching – not between Wi-Fi and caching. By having Wi-Fi compete in category 2 for caching we risk under-resourcing one of them.



So for caching to properly contribute to closing that Digital Divide, the key outcomes that are needed are firstly for

- districts to base their bandwidth upgrade decisions on a proper sense of relative value for money.

- funding for caching to be as readily accessible as funds for bandwidth.

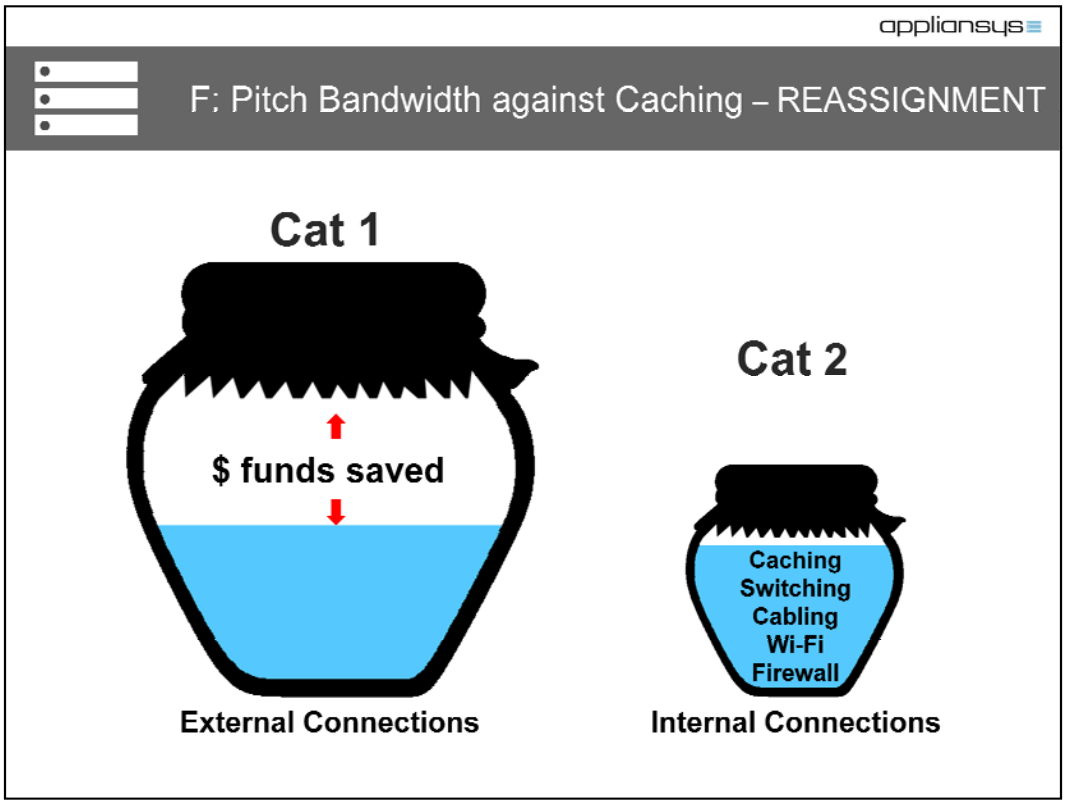
We need to ensure that schools can put in place adequate Wi-Fi AND caching and not be forced to choose between the two.

Competition for funding between bandwidth and caching on the other hand might be a thoroughly constructive development.

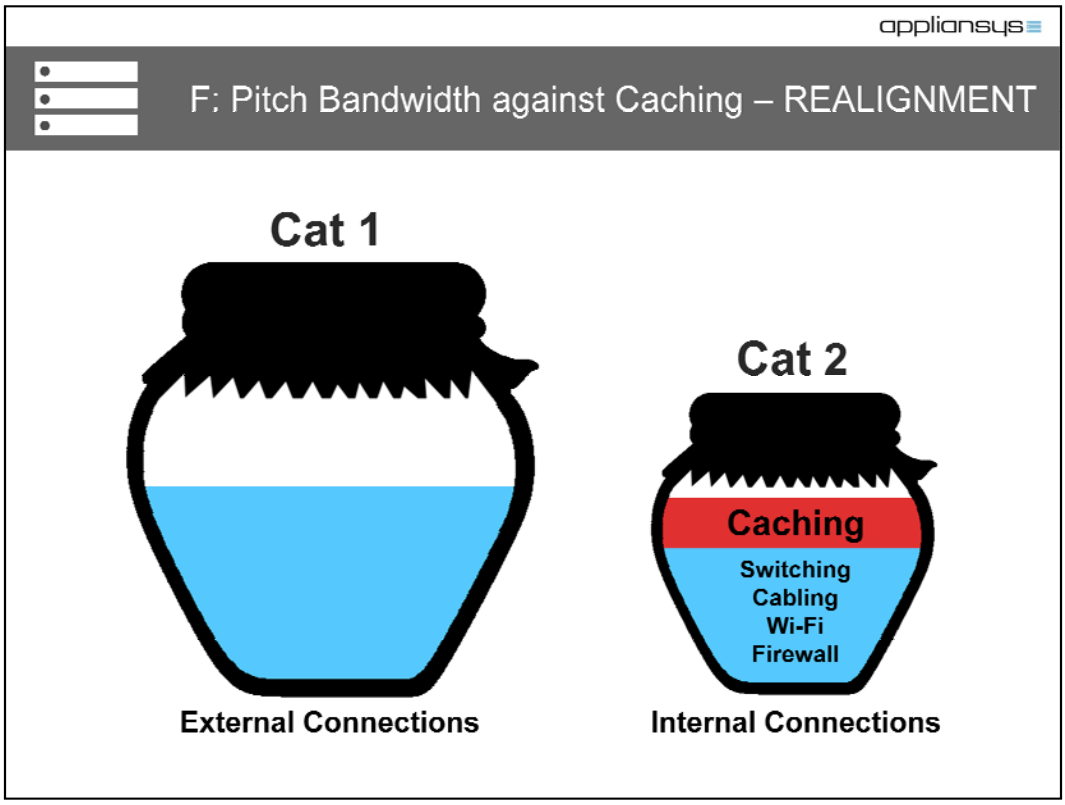
F: Potential of available levers

- FCC/USAC role
  - Evaluate data, resolve factors behind lag in uptake
  - Information for technology departments
- Connectivity Targets - currently Bandwidth capacity led
  - Consider a 'with caching' capacity target

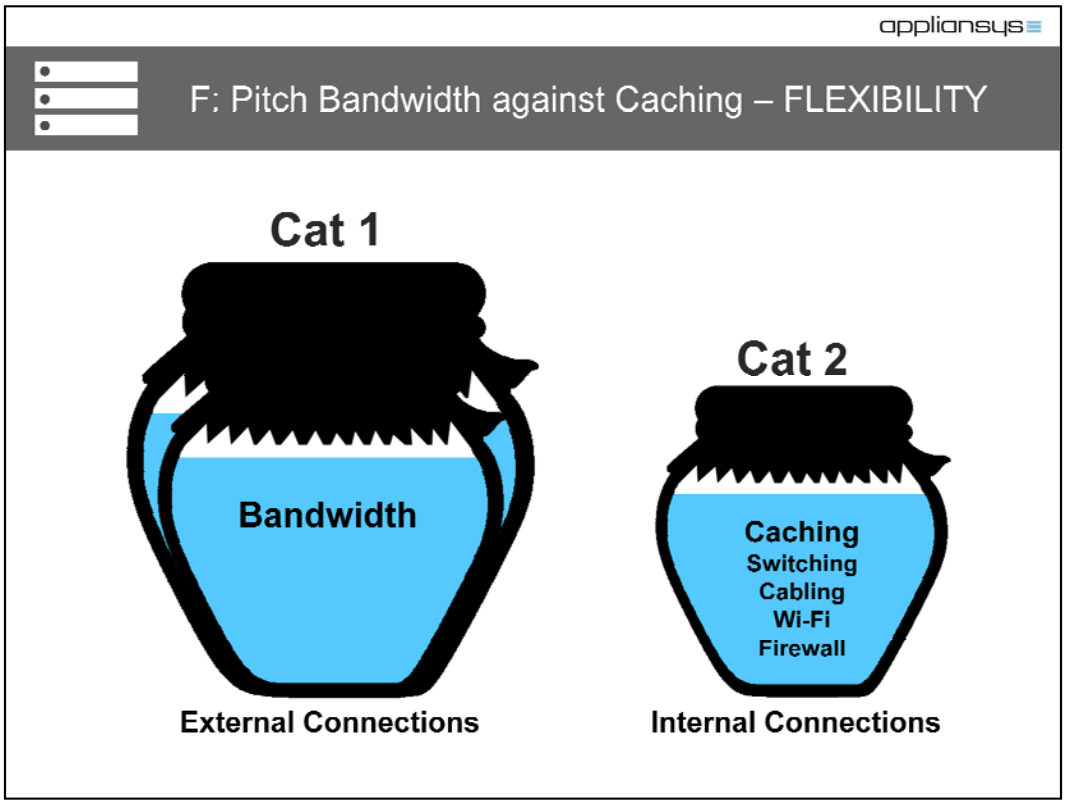
- Funding
  - Pitch caching against bandwidth to drive comparison
  - Drive proper disclosure and evaluation of caching options



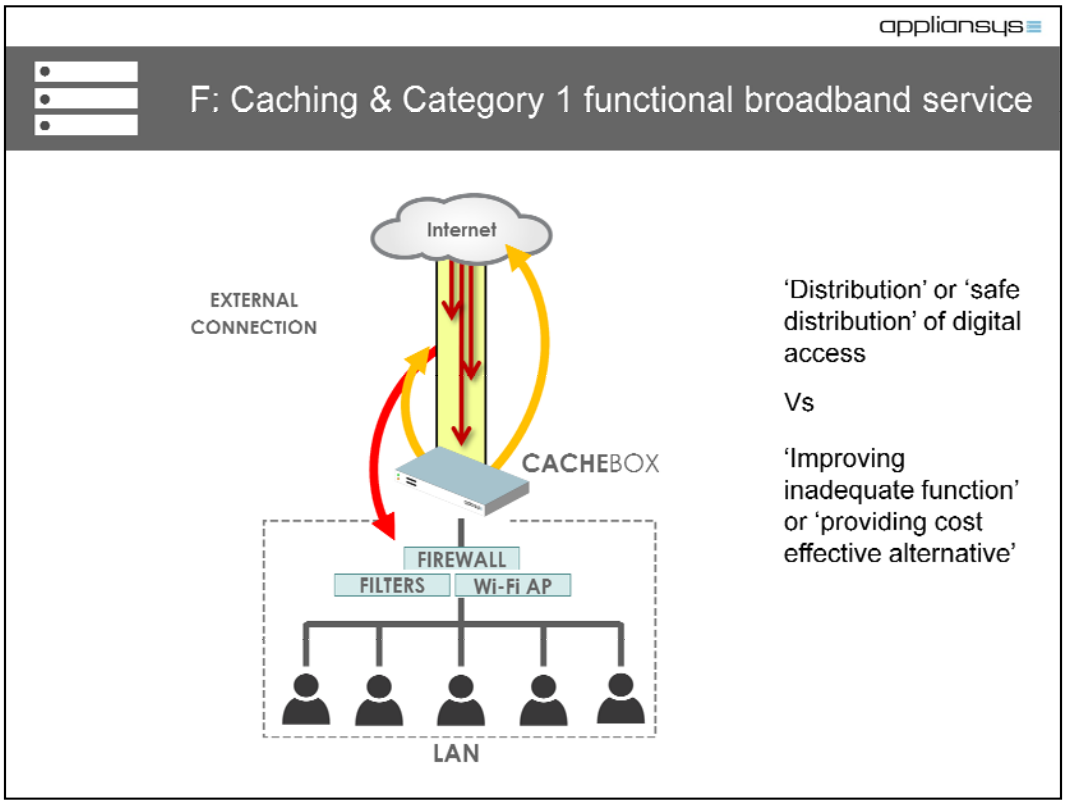
Scenario 1 - Move caching into Category 1 so schools would have to choose between them.



Scenario 2 - Cut Category 1 allocations globally and increase Category 2



Scenario 3 - Transfer some budget from Category 1 to Category 2 at the individual entity level (if a school chooses to not upgrade their bandwidth you allow them to roll a proportion of that across to their Category 2 allocation)



There appears to be reasons in favour of the first of those scenarios – Category 1 eligibility for Caching. A number of network technologies could lay claim to being "essential" for the correct functioning of External Links and therefore to being considered eligible for Category 1. But caching has the right credentials for this: Caches do indeed functionally - and usually topologically as well - sit between the external link and on-premises Category 2 LAN equipment.

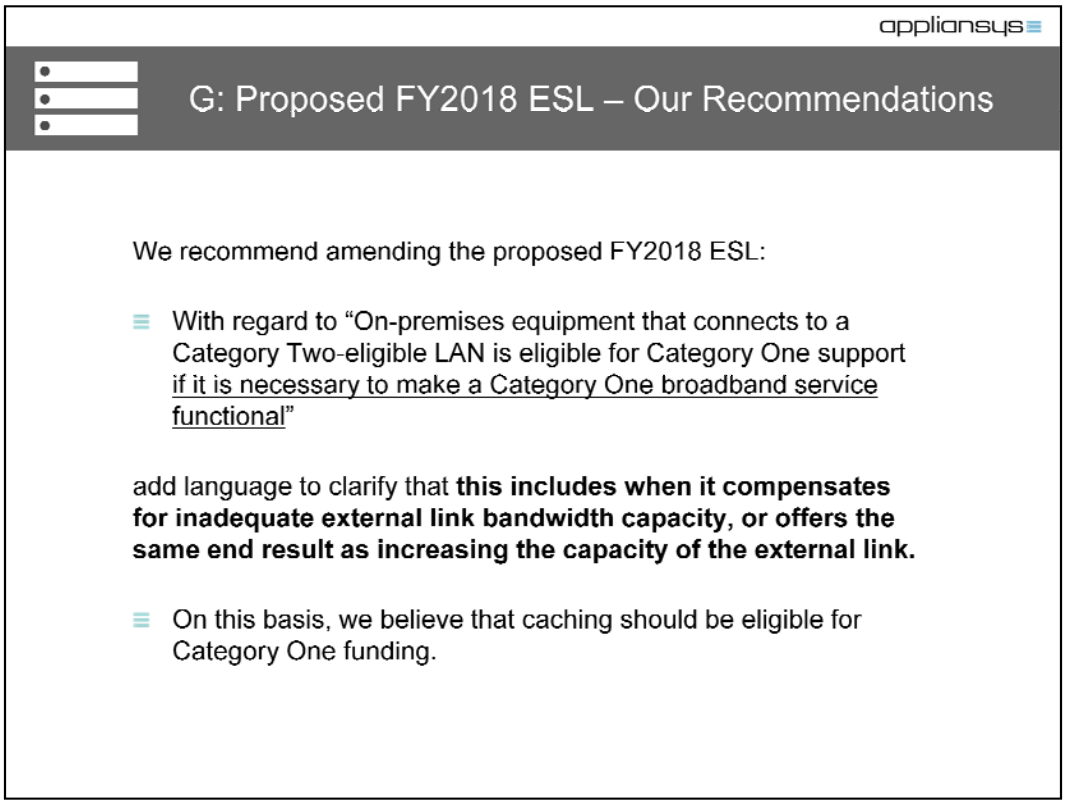
Their primary functions are:

1: to accelerate slow web-content being requested down that External Connection – improving broadband functionality even on multi-gigabit links

2: to provide a cost effective alternative to a bandwidth upgrade – reducing the amount of bandwidth capacity that needs to be maintained

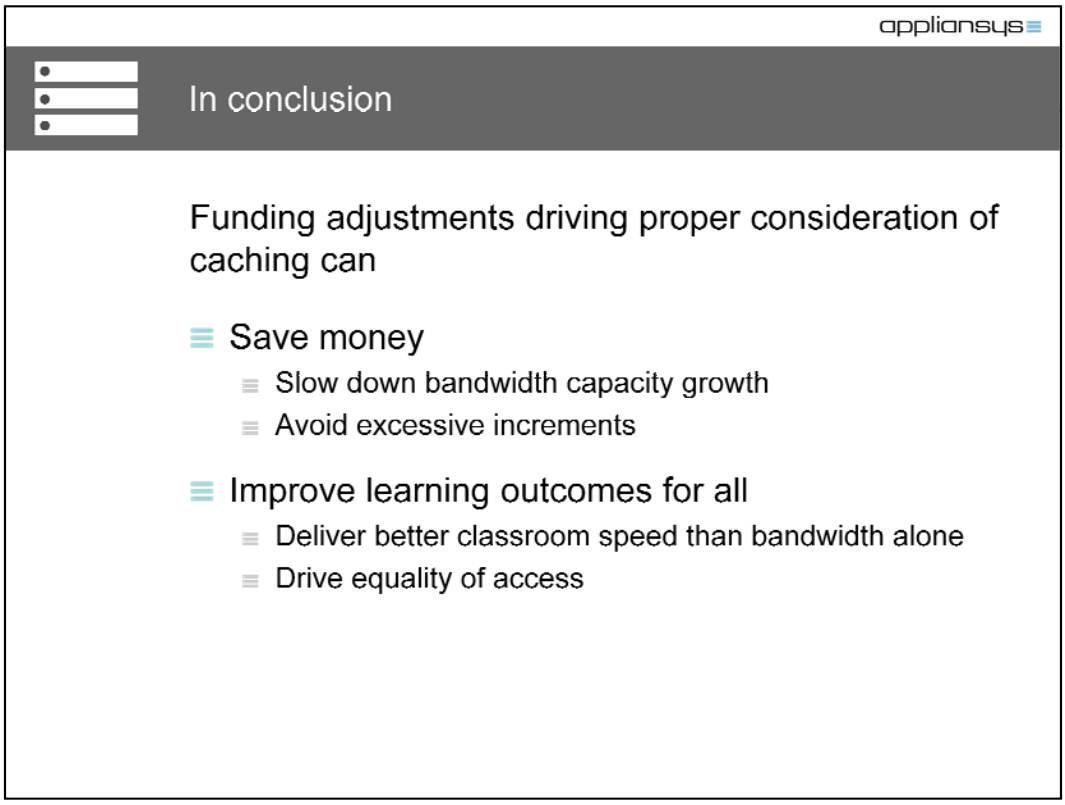
3: In so doing caching helps schools to avoid the associated costs of network equipment upgrades

So - while Wi-Fi and other Category 2 LAN devices either distribute or ensure the safe distribution of digital access provisioned by Category 1 external connections, caching both improves the functionality of existing links and is a replacement for a needed increment of bandwidth.



So we think that the clarifications currently under consideration around mixed eligibility equipment could be the fastest and simplest vehicle for pitching bandwidth up against caching in order to deliver widespread savings and at the same time improve connectivity for rural schools.

We offer a suggestion for additional clarifying language: that Category1 support would be available where the equipment is necessary to make broadband functional, including where it compensates for inadequate link capacity, or offers the same end result as increasing the capacity of the link.



The combined effect of the right combination of actions we advocate won't obviate the need for bandwidth upgrades.

But it will slow them down and avoid excessive increments.

If a school spends more money on bandwidth before adding caching to their tool-set – the chances are they will be throwing money down the drain.

If schools deploy caching instead of the next bandwidth increment they can:

- save money on bandwidth
- save money on infrastructure spend
- make browsers more responsive and reliable
- increase student engagement
- improve learning outcomes
- extend the curriculum of web-enabled learning
- satisfy budget holders, funding bodies and the tax payer
- move faster towards closing the digital divide

APPENDIX for Section C

A dossier of case studies illustrating the 4 key performance and value performance outcomes of caching deployment in K-12:

Improved functionality

1: Digital Access for bandwidth constrained schools

2: Speed improvements - for both metropolitan and rural

Improved Return on Investment -

3: $ savings on bandwidth costs

4: $ savings on Infrastructure upgrade costs

C: Assessment of impact of caching in US K-12

1: Digital Access for bandwidth constrained schools

- Sioux Central, IA
  - 35Mbps link, 140Mbps peak delivery
- Miami-Dade County Public Schools, FL
  - 30s page loads slashed to 2.5s
  - 97% from cache
- Maine School Admin District 49, ME
  - 1:1 made possible, iPads back in use

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2: Improved Functionality: Speed for rural - & metro

- Trinity School, MD
  - 50Mbps = 130Kbps/student
  - 350Mbps delivered by cache
- Laurens County School District, SC
  - 175Kbps/student on 1Gbps link
  - Classroom content 10x faster
- Anaheim Union High School District, CA
  - 31k students, 400Kbps/student on 10Gbps link
  - Almost all software from cache
  - Classroom content 10-50x faster

C: Assessment of impact of caching in US K-12

3: Improved ROI: Bandwidth

- Woodland Community Consolidated SD, IL
  - 128Kbps per pupil slashed to 18Kbps
  - 250Mbps link + cache saves £150k over 5 years
- Westwood Community School District, IA
  - 1,923Kbps/student
  - Vital classroom content too slow
  - Caching accelE-Rates more than 20x faster

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4: Infrastructure spend reduced

- San Bernardino CA & McGregor ISD, MN
  - Avoiding Firewall/Filter upgrade
- St Paul Public Schools, MN
  - Delays WAN to 10G & Internet link to 20G + network kit
- Cascade Public Schools, MT
- St. Labre Catholic Indian Schools, MT
  - Rural, small-school networks avoid upgrade
  - classroom 20x faster, software 300x faster
- Anaheim Union High School District, CA
  - 10G Internet partially utilised, target predicts 20Gbps

C: Assessment of impact of caching in US K-12

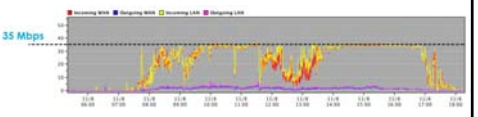
Improved Functionality: Access for Bandwidth constrained

Sioux Central Community SD Profile

613 students | 3 schools | Small, Remote

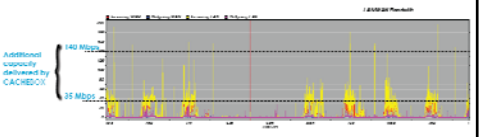
Challenge

- Simultaneous start of lesson video access was too slow in the classroom
- Remote location means bandwidth cost is prohibitive
- Peak traffic demand reaching 140 Mbps despite existing 35 Mbps connection



Impact of caching

- Serving content locally at LAN speed, drastically slashed load times
- Serving repeat video content from cache enabled peak traffic demand to be handled comfortably



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C: Assessment of impact of caching in US K-12

Improved Functionality: Access for Bandwidth constrained

Miami Dade County Public SD Profile

322,000 students | 462 schools | 30Gbps

Challenge

- 220 district schools are remote with small Internet connections
- Constant traffic congestion and latency meant lost learning time reaching many minutes in just a single lesson

Impact of caching

- Serving content locally at LAN speed, drastically slashed load times
- Serving content from cache also freed up precious bandwidth, making the 3% of dynamic content not served from cache also much faster to load.

Caching can help provide equitable access to accelE-Rated e-learning in remote schools.

	Requests	Total Load time
Without Caching	30 requests @ 1 sec each	30 seconds
With CACHEBOX	1 original file @ 1 sec + 29 requests @ 0.05 sec	2.45 seconds

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C: Assessment of impact of caching in US K-12

Improved Functionality: Access for Bandwidth constrained

Maine School Administrative District Profile

2,114 students | 6 schools | 95Mbps (former connection)

Challenge

- 1:1 unsuccessful on existing bandwidth link of 95Mbps. Teachers and students had to stop using iPads
- Large file downloads – such as software updates – hogged the connection and made the Internet unusable

Impact of caching

- Bandwidth 'hogs' taken off the WAN – updates cached and served locally
- Speed increase spikes of up to 400x for specific content

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C: Assessment of impact of caching in US K-12

Improved Functionality: Speed for rural - & metro

Trinity School, Maryland Profile

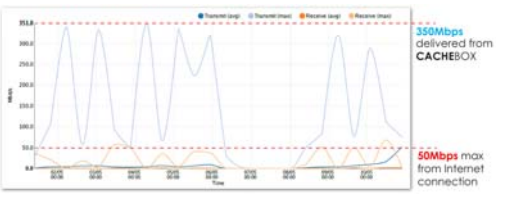
382 students | 1 school | 50Mbps connection

Challenge

- 50Mbps Internet connection maxing out most of the day due to students accessing media content on 1:1 iPads, Windows laptops and PCs
- No options for additional bandwidth, reached limit

Impact of caching

- Now getting throughput peaks up to 350-400Mbps from Cache
- That means average speed increase is 7-8x faster than what can be acquired on existing connection!
- *'If you have any issues with bandwidth, this is a good product to consider. I would buy it," David Godfrey, Trinity School*



NOTE
We are updating the following graphic on page 12 in our Comments of July 21 2017 for Trinity School, as follows:
The graph axis has been updated to reflect the 50Mbps in the text.

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Improved Functionality: Speed for rural - & metro

Laurens County SD Profile

9 Schools | 5,718 Students | Rural | 1Gbps

Challenge

- 1:1 learning rolled out to each of its 10 schools
- Despite bandwidth upgrade to 1Gbps, content was still slow in the classroom. “Coolmath” access in particular not responsive enough

Impact of caching

- Now caching and serving content over 10x faster on average – and almost 14 times faster for Coolmath content.

VOLUME of DATA			
Status	Transfer	% of total	KB/sec
TCP_HIT	802,752.11MB	25.0%	944.40
TCP_MISS	654,805.73MB	45.8%	86.72

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Improved Functionality: Speed for Rural & Metro

Anaheim Union HSD Profile

23,700 students | 20 schools | 10 Gbps connection

Challenge

- Despite a 10Gbps connection critical e-learning content still arrives slowly in classrooms causing delays in learning performance

Impact of caching

- Apex Learning is served 48x faster from cache than from the Internet
- SparkNotes is served 35x faster
- PrimaryGames.com is served 27x faster
- HistoryontheNet.com is served 10x faster

Domain	From Web (Mbps)	From CACHEBOX (Mbps)	Speed increase (times)
*.apexlearning.com	0.97	47.05	48.5
*.sparknotes.com	0.16	5.78	35.8
*.lkqd.net	0.46	16.47	35.8
*.rosettastone.com	1.23	38.22	31.0
*.primarygames.com	1.01	28.18	27.9
*.aeries.com	3.32	51.41	15.5
*.primarygames.com	2.40	29.96	12.5
*.unity3d.com	0.21	2.50	12.1
*.mcafee.com	3.64	42.49	11.7
study.com	0.96	10.62	11.1
*.historyonthenet.com	2.12	22.85	10.8
*.anaheim.net	4.06	39.75	9.8
*.googlevideo.com	6.80	54.69	8.0
*.autodesk.com	6.72	45.53	6.8
*.macromedia.com	9.47	43.84	4.6
*.mhpracticeplusap.com	8.88	31.98	3.6

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Infrastructure Spend Reduced

Cascade Public SD 3 Profile

286 students | 3 schools | 45 Mbps connection

Challenge

- Running 400 devices on 45Mbps
- High cost on bandwidth @ $25k/y
- Upgrading bandwidth would require network kit and infrastructure upgrading

Impact of caching

- Serving content locally enables classroom delivery at 250Mbps
- Windows updates from cache can reach 376Mbps/device
- Existing infrastructure unchanged, extended lifecycle and increased return on existing investment

Caching is significantly more affordable than an infrastructure upgrade to a school's network, and enables schools to maximise existing investment

See Appendix for schools solving similar problems : St Labre, Saint Paul, Durant and Anaheim

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C: Assessment of Impact of Caching in US K-12

Infrastructure Spend Reduced

St. Labre SD Profile

150 students | 1 school | 150 Mbps connection

Challenge

- Remote school with an expensive connection ($2,100 per month)
- Further upgrading would be an unaffordable and unnecessary option

Impact of caching

- **CACHE**BOX solution handles peaks in demand at 280 Mbps
- Traffic from cache is recorded being accelE-Rated 22x faster than form the Internet
- Increasing effective capacity saves on higher bandwidth fees and postpones the need for an infrastructure upgrade

Traffic Summary

Bandwidth Total	9.88 GB	Average Object Size (direct)	5.15 KB
Bandwidth Saved	5.25 GB	Average Object Size (from cache)	58.5 KB
Bandwidth Savings (%)	53.09%	Unique Domains	1,977
Requests Total	991k	Unique Sources	288
Requests Saved	89.7k	Average Speed (direct)	148 KB/s
Request Savings (%)	9.05%	Average Speed (from cache)	3.33 MB/s

C: Assessment of impact of caching in US K-12

Infrastructure Spend Reduced

Saint Paul Public SD Profile

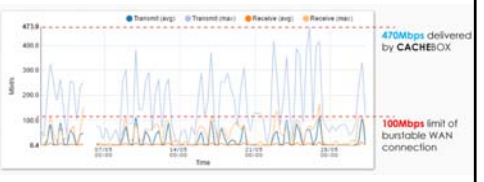
37,000 students | 72 schools | Urban | 500kbps per student

Challenge

- Demand is 'bottlenecked' by each school's 100Mbps WAN link to a single Data Center, causing slow classroom delivery
- The one-off costs of upgrading WAN links to 72 schools from 100Mbps to 1Gbps is enormous

Impact of caching

- Despite the 100Mbps bottleneck:
  - Content served from cache is 10-15 times faster on average, up to 200 times faster than Internet
  - 470Mbps of demand is being delivered
- With a **CACHE**BOX solution Saint Paul can continue to **benefit** from its **existing infrastructure investment** and postpone any costly upgrade



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Infrastructure Spend Reduced

Durant Community SD Profile

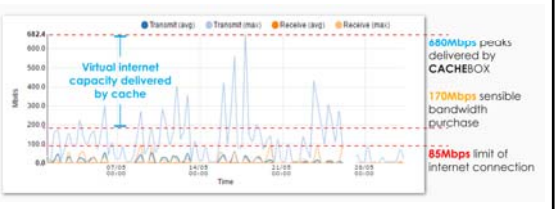
673 students | 3 schools | Remote, Rural | 126kbps per student

Challenge

- Simultaneous start of lesson delivery of video and learning content is too slow in the classroom
- Rural location means bandwidth costs are extremely high
- Infrastructure costs to upgrade from 1Gbps to 10Gbps prohibitive

Impact of caching

- Content delivered from cache is 5, 8, 20+, even 80 times **faster**
- **No change** required to infrastructure – Caching uses existing cabling, routing and switching, firewall, etc



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Infrastructure Spend Reduced

Anaheim Union HSD Profile

23,700 students | 20 schools | 10 Gbps connection

Challenge

- Upgrading bandwidth to 20Gbps at Anaheim will require huge network infrastructure builds and upgrades from cabling, to routing and switching, firewalls, etc

Impact of caching

- Serving content from cache reduces the strain on the connection, and necessitates the need for upgrade
- Increasing effective capacity through caching postpones the need for an infrastructure upgrade, and maximizes return on existing investments.

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C: Assessment of Impact of Caching in US K-12

Improved ROI: Bandwidth

Woodland SD 50 Profile

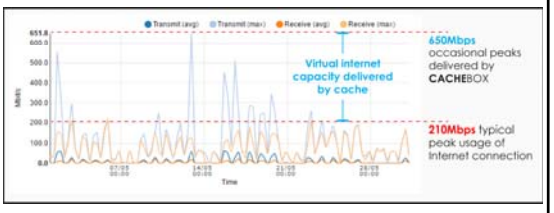
4 Schools | 6,190 Students | Suburban | 250Mbps

Challenge

- With just 250Mbps shared by 6,000+ students, the district was below the FCC's minimum 100 Kbps/student 2016 target. To reach this it needed 370Mbps at an additional $2,000/month
- Additional 360Mbps to reach FCC target: $21,900 per annum for bandwidth that's needed 4-5 times per month.

Impact of caching

- Woodland's **CACHE**BOX solution costs $7,450 - with expected lifecycle c. 5 years.
- **CACHE**BOX pays for itself in 4 months and saves the district and FCC over $100k in its full lifecycle!



See Appendix for schools solving similar problems : Woodland

C: Assessment of impact of caching in US K-12

Improved ROI: Bandwidth

Westwood CSD Profile

520 students | 2 schools | 1 Gbps connection

Challenge

- Remote school with an expensive connection ($3,127 per month), high cost per student
- Further upgrading would be an unaffordable and unnecessary option
- Next upgrade step requires 10Gbps-ready infrastructure – new routings, switching, cabling, firewall, Wi-Fi access points...

Impact of caching

- Serving content locally at LAN speed, drastically increased bandwidth capacity, making dynamic content more available.
- Cached content can serve repeat requests while maintaining spare capacity for new content, unlike bandwidth upgrades, where demand will rise to meet capacity.

NOTE

We are updating the following sentence on page 14 in our Comments of July 21 2017 for Westwood Community School District, as follows:

"Educational content that comes directly from the Internet still arrives slowly – as low as 0.06-0.08Mbps."

C: Assessment of impact of caching in US K-12

Improved ROI: Bandwidth

Oak Grove R-VI SD Profile

1,965 students | 4 schools | 1 Gbps connection

Challenge

- Running an expensive connection ($5,018 per month)
- High cost per student to achieve 5 times the target of 100kbps
- Despite bandwidth upgrade to 1Gbps, content delivery in the classroom is not as fast as expected.

Impact of caching

- Serving content from cache means it can be delivered locally at LAN speed
- Educational content is up to 55 times faster:
  - Sharpschool.com = 55.05x
  - Qubo.com = 27.54 x
  - Abcya.com = 26.30 x
  - Starfall.com = 18.86 x
  - Netsmartz.com = 11.84 x